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SPECIAL SHUTTLE ISSUE

NASA Magazine, your new information source, premieres this spring with a special Education Issue

THIS ISSUE

This issue of NASA Activities is a departure from our customary format. It is dedicated almost exclusively to that remarkable space transportation system, the Space Shuttle.

But looking back, we remember the halcyon days of the Mercury Program and its seven original astronauts. Brave men who risked their lives on types of rockets that not too long before, had been seen blowing apart over the palmetto of mid-coastal Florida. **Then came Gemini. We were beginning to learn to work in space;** rendezvous and docking and spacewalks. **The ultimate historical space travel statement was perhaps made by Apollo. The first man on the moon!** But many had seen the handwriting on the wall; if we were going to explore space, it would have to be on a more economical footing. It was in that light that the Space Shuttle was conceived.

This issue of NASA Activities was conceived during the doldrums of summer, a time of testing for many on the Space Shuttle team, as well as others. The Shuttle, so symbolic of NASA, gained the glare of not-always-so-friendly media attention during the period. **But it brought to mind that despite its transitory technical problems, the Space Shuttle is still the remarkable technological marvel it was meant to be.** We hope you find this special issue of NASA Activities stimulating, entertaining and useful! — *Ed.*

Next Issue:
A Review of a Year of Accomplishments

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Astronaut Candidate Ellen Ochoa gets the feel of handling a parachute in a survival training exercise at Vance Air Force Base. Ochoa is one of 23 astronaut candidates who began a one-year training and evaluation regimen in July. The parachute training familiarizes the candidate with safety gear in the event of an emergency ejection from a jet aircraft.

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OFFICIAL COMMENTARY

The Demythification of NASA

By John Lawrence, Director of Policy and Plans, Office of Space Flight, NASA Hq.

It's axiomatic — perception is more important than fact. And if that isn't sufficiently bizarre, consider the new law which has lately come into play in some circles. It should be known as "the NASA Corollary" — fact and opinion may be not only unrelated, but at polar extremes.

One explanation for the phenomenon is something akin to the old Indian adage that your greatness is measured by the strength of your enemies. The legion of self-described adversaries and watchdogs may reason that if they're wiser than NASA, then they are wise indeed. It's flattery of a perverse sort, that such self-aggrandizement is at NASA's expense. What is particularly perplexing, however, is that the ridicule is generally in the form of opinions that come from partial information, misinformation, or (there's no sweet way to say it) absolute ignorance of the facts.

Given the aforementioned axiom, the effect of such commentary is worrisome. NASA operates in a climate which requires the confidence of the White House, Congress, the public, and international partners. The extent to which this hostile barrage effects the space program is difficult to measure. Although an admittedly imprecise science, the literature of the communications field is remarkably consistent in its assessment of how opinions and attitudes are shaped. No evidence suggests that journalists or public figures have a direct impact on the public conscience. Rather, attitudes tend to be influenced by a group loosely identified as "opinion leaders." It is an ethereal group, never precisely defined. The prevailing notion is that opinion leaders are almost always personal contacts such as friends or family members, who have first, second, or third-hand sources into an issue.

John Lawrence

By inference, the extended circle of NASA/contractor employees, their families and friends, can be opinion leaders on issues regarding the space program and can be influential in shaping attitudes. Luckily, the misperceptions they must repudiate do not stand up well against the facts. Toward that end, the following is a synthesis of opinions voiced about NASA in recent years that can be filed under one of these major categories. Each perception is followed by the facts which renounce it.

PERCEPTION: NASA has no clear sense of purpose or direction, that it is in the words of one news magazine "Lost in Space".

FACT: Quite the reverse is true. Unlike past programs, such as Apollo and Skylab which were of a fixed duration, today's strategy is logical and incremental growth into the future. The intent of the Space Exploration Initiative is to make humans permanent explorers and travelers in our solar system.

With the Space Shuttle and Space Station Freedom as the enabling technologies, the agency's long range objectives include a lunar outpost and a crewed excursion to Mars. It is significant that the lunar colony is envisioned as a permanent outpost. It will be analogous to the scientific stations operating in earth's polar regions, which depend upon resupply to sustain their operations, and support communities varying from a few to several dozen scientists. This colony, in turn, will be the technology which enables the Mars voyage. Never have NASA's objectives been so clear.

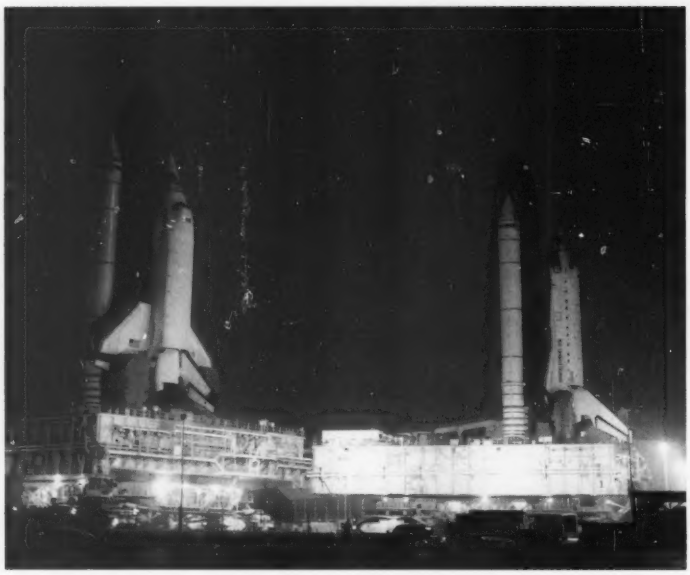
PERCEPTION: The Space Shuttle is an ill-advised program and an illogical space transportation system.

FACT: Any spacefaring nation would characterize an optimum transportation system as being a reliable, reusable, man-rated, heavy-lift booster, carrying crews and significant cargos to and from space — the very definition of the Space Shuttle program. The designs of ESA's Hermes and the Soviet Buran are not a coincidence — their pedigrees are of obvious origin. The Space Shuttle is a logical progression from the early manned flight programs, and is the critical capability which makes Space Station Freedom possible, as well as the objectives of the Human Exploration Initiative.

continued on next page

PERCEPTION: The Space Shuttle program falls far short of its promised capabilities.

FACT: This argument usually rests on the 1970s estimates of up to 60 Shuttle flights per year, which by current standards is clearly unattainable. What these critics fail to recognize is that the early number was a best-case projection, based on a fleet of six orbiters with simultaneous launch operations at Kennedy Space Center, Fla., and Vandenberg AFB, Calif. Manpower, budget and acquisition of new facilities have also not materialized as projected. While Shuttle turnaround times have not been as good as was hoped, the story is nowhere near as dismal as critics suggest.



PERCEPTION: The Space Shuttle is fragile and is crippled by technical problems.

FACT: Many critics want to apply assembly line values to the space program, as though it were comparable to the manufacture of automobiles. Such views come from the simple failure to grasp the enormity and complexity of the program. The Shuttle is a singularly unique system unlike anything else in operation, and a great deal remains to be learned about it as operations continue. Problems, such as recent difficulties with hydrogen leaks, will continue through the duration of the program and must be regarded as inevitable and the natural consequence of moving technology forward.

PERCEPTION: Space Station Freedom is conceptually unsound.

FACT: This perception results from a very shallow understanding of the Preliminary Design Review (PDR) process. The PDR is the point at which the program makes a "reality check" by comparing its specifications to its capabilities. It is a given that, going in, costs, weights, man-hours, and a number of other ingredients will be prohibitively high. But this process scrubs programs back to realistic levels to ensure compatibility with program requirements. Nevertheless, preliminary figures have resulted in criticism that the program is fundamentally flawed. In fact, the results of these reviews have been expected; many minor issues to work, a few more significant issues, but no "show stoppers." Apollo, Skylab, Space Shuttle, and all other major programs have passed through the PDR process, and Freedom is in good order by comparison. Despite funding instability, the program passed through FY 1990 adjustments without an increase in total development cost. The first element launch date is unchanged and the program remains on budget. FY 1991 raises concerns due to the threat of another destabilizing budget shortfall, but these problems are of a fiscal nature and are unrelated to program planning, design or engineering.

PERCEPTION: No market demand exists for Space Station Freedom.

FACT: The program has a large and enthusiastic constituency of domestic users and international partners. In fact, Freedom is already fully utilized in terms of available power and rack space.

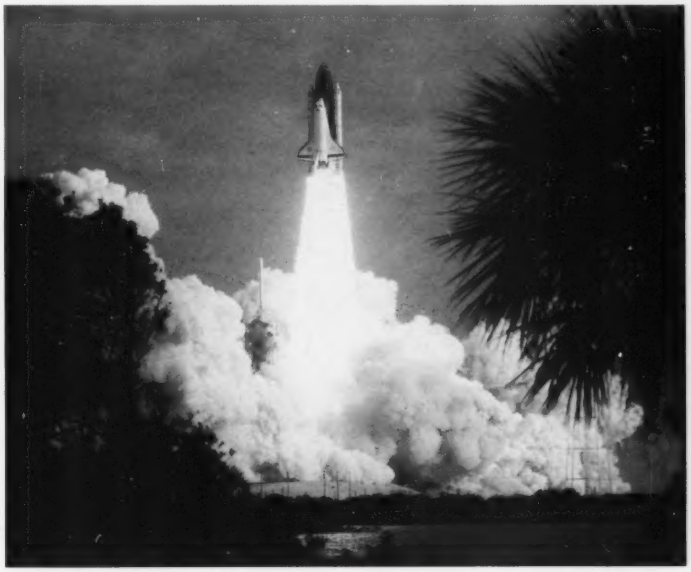
PERCEPTION: NASA prefers big, costly programs and resists the "Big Dumb Booster" concept.

FACT: "Big Dumb Booster" is a catchy phrase which suggests a heavy-lift booster system can be developed with raw power, but without high-tech and expensive avionics and electronic sophistication. Realistically, costs increase proportionally with payload capability. The argument that costs might be cut by reducing levels of sophistication, does not recognize that sophisticated systems, testing, and the redundancy which drives costs up, translate into reliability. It is also true that nothing is more costly than low reliability. No

launch customer is going to want to put a very heavy (and hence, very costly) payload on an unreliable booster.

PERCEPTION: NASA has grown excessively large in budget and manpower.

FACT: By any measure — as a fraction of the federal budget, relative to Gross National Product, or by any other economic indicator — the NASA budget has declined in relative terms for the past two decades. At its peak during the Apollo program, NASA received more than four percent of the Federal Budget. During fiscal year 1990 the agency's budget was 1.6 percent of the total. The number of NASA employees peaked at close to 36,000 in fiscal year 1967. Presently the agency is smaller by approximately 1/3, with fewer than 24,000 employees.



PERCEPTION: Federal expenditures on the space program are detrimental to the national economy.

FACT: A number of independent studies show NASA programs promote economic growth with cost-to-benefit ratios as low as $6-to-$1, up to as high as $35-to-$1. Chapman Research Group Inc. recently contacted more than 400 companies to evaluate the impact of NASA spinoffs, and estimated cost savings of $22 billion from applied technologies. In 1988 the Nobel Prize in Economics went to an MIT professor, Dr. Robert Solow, in part for his work on a mathematic model which showed how a culture's economy prospered from its investment in technological progress. NASA's expenditures do not somehow vaporize in space — they are invested in the American economy and industry.

PERCEPTION: Public support for NASA has eroded.

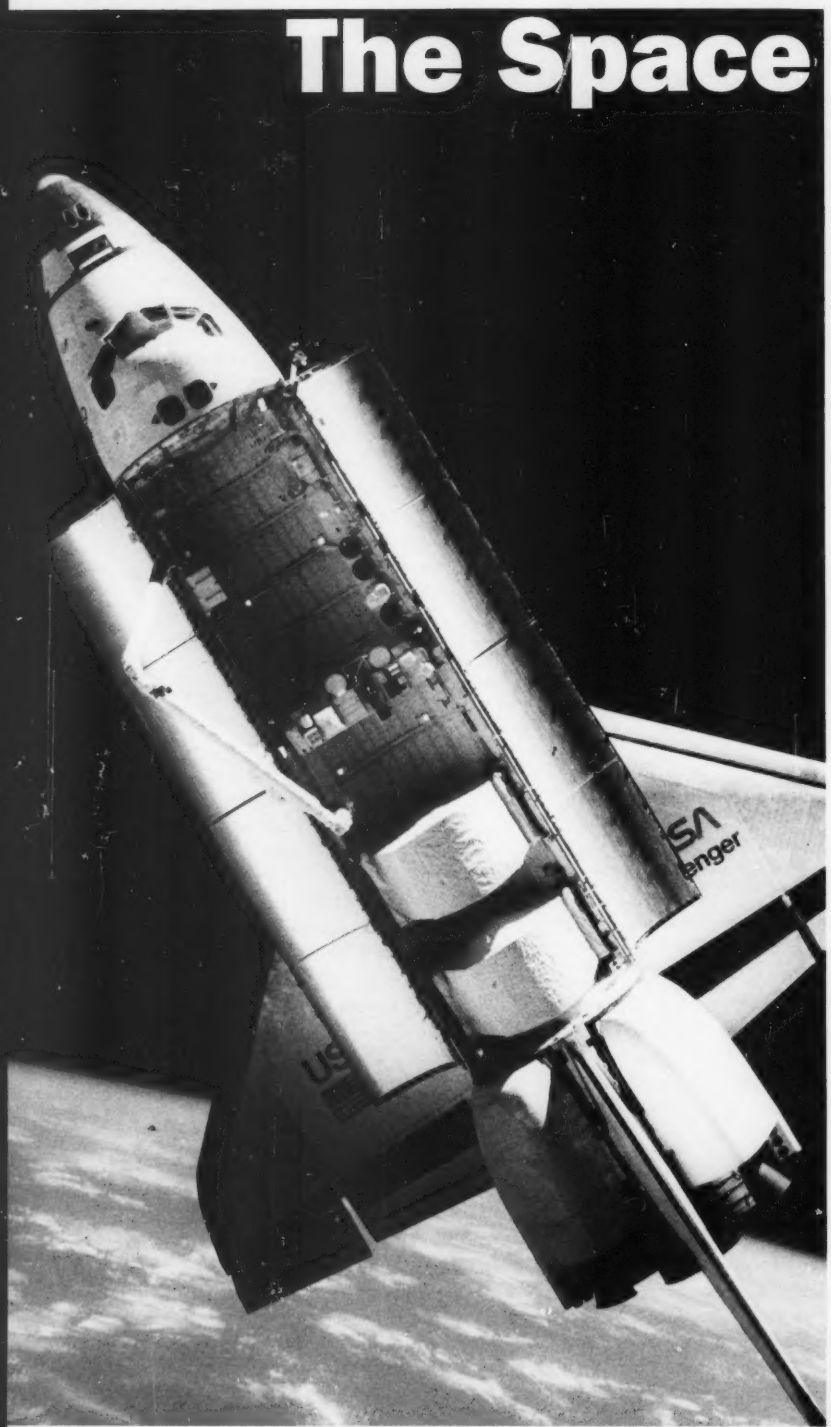
FACT: Every indicator of public interest in NASA is at its highest level. These include volume of public mail, numbers of visitors to the NASA field centers, Speakers Bureau requests, and educational requests from both teachers and students. Public opinion surveys consistently show approximately 80 percent approval rating for the agency, and a similar percentage believe NASA funding is adequate, or should be increased. Moreover, Congress has increased NASA's budget steadily over recent years. In a zero-growth budget environment such as is legislated under Graham-Rudman-Hollings, this is a genuine gesture of support.

It is interesting to note by comparison the numbers of media covering manned launch operations. Apollo 11 and STS-1 were high points with approximately 2,700 media attending each of those launches. By the 10th Shuttle flight the number dropped to 883, and Mission 61-C — the flight immediately prior to the Challenger accident — attracted 380 news media representatives. The Oct. 6 launch of Discovery drew 554. These figures warn against confusing public interest with media interest.

...Innovation, Resiliency, Skill...

The point is not that NASA is perfect. Human frailty and fallibility assure that nothing we do will ever be perfect. The Apollo program encountered difficulties, as have unmanned missions such as Viking to Mars, Voyager which toured the planets, and Magellan to Venus. Yet in each case the resiliency, innovation, and skill characteristic of NASA has persevered. Most observers outside the aerospace community can't know programs and operations in sufficient detail to appreciate this, and accordingly are vulnerable to misinformation. The only way to to dispel these misconceptions is with fact, and the only one who can do it is you. ■

The Space Shuttle



The Space Shuttle remains the most sophisticated, technologically advanced manned spaceship in the world and is likely to be for some time. No other vehicle can do what it does.

During the 1960s, several studies of a re-usable manned spacecraft were conducted. In April 1969, NASA's Space Shuttle Task Group was established, and in January 1972, as the last two Apollo missions prepared to fly to the Moon, President Nixon announced that nation would proceed with the Space Shuttle.

The United States developed the Space Shuttle system to greatly improve its access to space, and for almost eight flight years, during which 38 successful missions have been flown, the Shuttle has done just that.

The following articles help provide a perspective of the Space Shuttle and its accomplishments.

in Perspective

"Making a Good Space Shuttle Better"

By Donald F. Robertson

(The following is an excerpt from the "Commentary" column of SPACE NEWS, Oct. 8-14, '90.)

Shuttle bashing has been a national sport. Much of this is NASA's fault since they vastly over-sold the space shuttle. The hype, together with relentless under-funding, resulted in a vehicle that will never achieve many of its advertised goals.

While deciding whether to fully fund the forthcoming international space station, Congress should step back and look at the shuttle program in perspective.

Recall the heady days of Gemini and Apollo, when launching a human spacecraft took most of NASA's resources and delivered only two or three astronauts in a cramped cabin with little room for experiments.

Even Skylab, the exception to this rule, was an expensive one-shot affair.

The highest flight rate ever achieved for the Saturn launch vehicle was five per year — with what amounted in the early years to a blank check.

If the shuttles do not fly with the regularity that NASA hoped, they have achieved a flight rate substantially better than the Saturn program ever did, and they do it while the space agency is simultaneously conducting several other major projects. The shuttle flew nine times in its busiest year, 1985, and five times in 1989.

All this has been accomplished while NASA received much less money than it did during Apollo. Apollo-era budgets peaked at a bit more than $5 billion in 1965; a Congressional Budget Office source says that amount is equivalent to more than $22 billion in 1990 dollars. NASA's 1990 budget is about $12.3 billion.

NASA's great achievement with the shuttle, fulfilled in the presence of immense political and financial adversity, was to build a vehicle that delivers seven astronauts and a huge experimental payload into orbit.

> "In the long run, the shuttle is likely to prove far more reliable than any expendable."

No expendable rocket ever achieved its first 35 flights with only a single catastrophic failure (although the Saturns came close).

Compare this with the world's most modern expendable rocket, the European Ariane series, which lost four vehicles in a comparable number of flights spread over a greater period of time.

In the long run, the shuttle is likely to prove far more reliable than any expendable.

Seen in this light, the shuttle's capabilities are impressive indeed. They were achieved with the world's first reusable spacecraft, essentially an experimental vehicle.

Expendable rockets are mature if ancient technologies, and probably are near the low ends of their cost curves.

The first-generation shuttle is a new technology, as expensive as it ever will be.

Even that is not the entire story. We should consider the 175,000-pound shuttle orbiter as payload, not just the 50,000 pounds the orbiter can carry to space in its cargo bay. Seen in this light, the shuttle launch system is more cost efficient at delivering a pound to orbit than is any expendable. Even given... pessimistic [launch rate] figures, lofting the orbiters and their payloads cost about $3,000 per pound, compared to about $4,600 per pound to loft payloads on expendable rockets such as the Delta 2 and Atlas-Centaur.

The shuttle's most important success has nothing to do with operations. The program provided a flight demonstration of every technology needed for routine, reusable spaceflight save one: a reusable cyrogenic propellant tank.

Because of the shuttle program, the nation can now proceed with the Advanced Manned Launch System, a second-generation shuttle idea from NASA's Marshall Space Flight Center; derivatives of the national aerospace plane; and other second-generation vehicles with greater confidence of economics, as well as technical, success. ■

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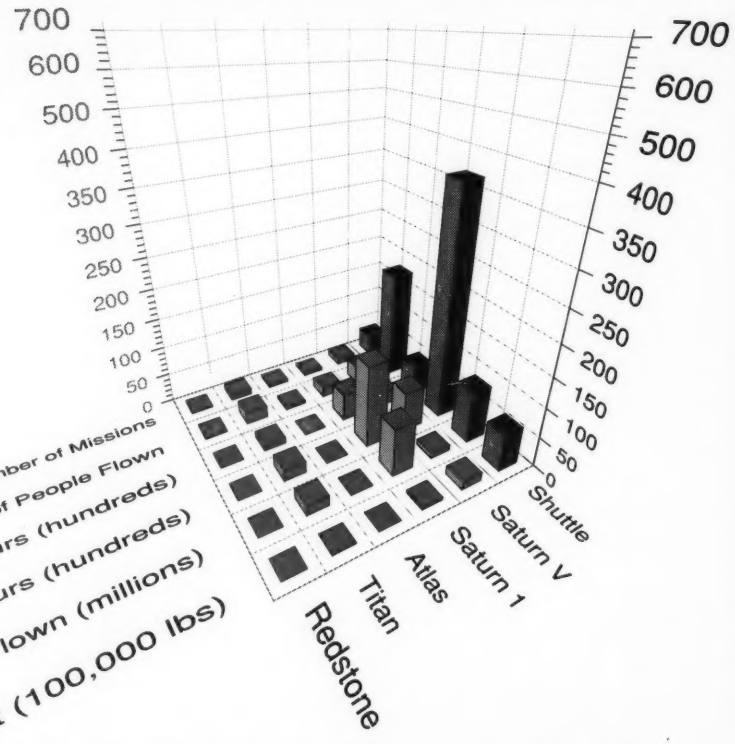
Just How Does the Shuttle Stack Up?

By any measure, the shuttle has moved to the front of the line in terms of capabilities for U.S. man-rated launch vehicles.



In 1970, by most accounts, NASA was promising that once the shuttle was developed, space flight would be frequent, routine and cheap.

While it is true the shuttle has not fulfilled the claims of its most ardent early supporters, a review of what the shuttle *has* accomplished — especially in comparison to previous manned launch vehicles — offers some impressive facts.

Today, some say that NASA has failed to deliver on promises that space flight would be frequent, routine and cheap.

What has happened since 1981 when Columbia initiated the age of the reusable space vehicle. Well, for one, at the conclusion of the November STS-38 Atlantis mission, the shuttle had flown seven more missions than all previous manned space flight programs staged by the United States. Not only that, the shuttle has flown two-and-a-half times as many individuals into space and brought them back, as all the previous launch systems the U.S. has used combined.

The Titan lofted twenty humans into space on ten separate missions in a frantic 602-day period from March 1965 through November 1966. The average "down" time between Gemini flights was 60 days.

The Saturn series, the 1B and V, boosted 45 humans into space. These 14 missions lasted through a period of some 1,477 days — four years — and averaged four months between flights. This is the vehicle which is repeatedly brought to mind by the pundits who wonder why the U.S. relinquished such a magnificent, powerful and serviceable vehicle. Nevermind the 1970 dollar cost of $350 million for each of the Saturn V vehicles we built.

Where does this leave the shuttle? It leaves the winged spaceplane in the lead.

Nearly ten years later the shuttle is still flying. Thirty-six shuttle missions have carried 186 individuals into space and brought them back — to fly again, machine and mortal alike. The average time between shuttle flights is 96 days. This is counting the re-engineering time following the Challenger accident. The actual flight rate is more like one mission every 70 days.

What this tells us is difficult to grasp from within the world of shuttle tanking tests and mission redesigns. But, in the nearly three decades since the U.S. has been flying humans in space, we have developed a capability to sustain a flight rate which only two decades ago was considered frenetic. One decade ago the shuttle began flight as the U.S. man-rated launch vehicle. Since then it has sustained a flight-rate interval unmatched by

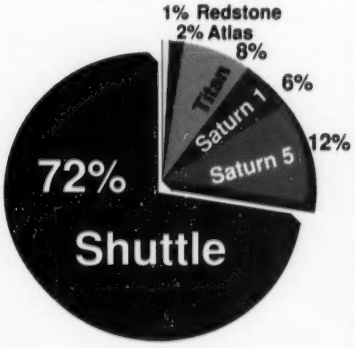
anybody's man-rated vehicle.

Criticisms of the shuttle aside, the fact remains that the only other time we were flying as frequently was over twenty years ago for performance testing and docking procedure development. The only time we have ever approached the average shuttle manhour numbers was during the Skylab missions — whose intent included the study of long-duration effects on humans and from which we evolved many of the shuttle's systems.

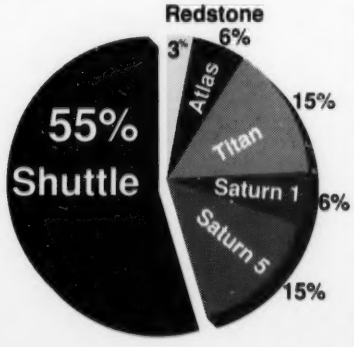
There are other numbers which tell a compelling story of how much we have evolved from those glory days of only a decade ago.

By virtue of the size of the orbiter's crew compartment and by virtue of its design all but the first six flights of the shuttle have had no fewer than five crew members. This has allowed for the development of a statistic which is never cited but which has added to the U.S. store of space habitability and workability knowledge. More different types of individuals have flown on the shuttle than all other launch systems combined - U.S. and Soviet.

Percentage of all Individuals Flown in Space by Vehicle

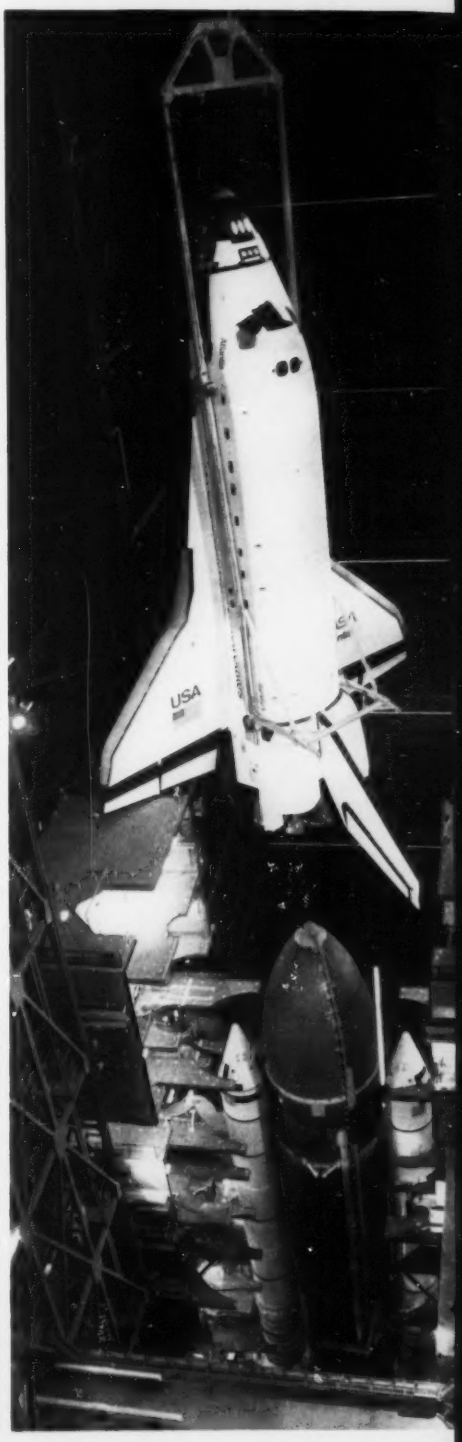


Percentage of all Manned Space Missions by Vehicle



The shuttle has allowed the U.S. to accrue space man-hours at an unprecedented rate. If the measure of a program's efficiency is its ability to extract additional productivity with little or no additional investment, then the shuttle has dramatically transformed human space productivity. Every shuttle mission flies with secondary payloads and most of them require some crew interaction. Each flight has a shopping list of engineering, procedural and scientific test objectives. Each flight has multiple levels of photo and voice documentation. Every time a shuttle lands it brings back five or more humans whose experience and imagination add to the total knowledge base of spaceflight.

This productivity can actually be measured using the simple analysis alluded to earlier. If a program's total capital investment during the lifetime of the program is described as the "cost," and the number of man-hours accrued during that program's life is measured and divided into that cost, the price of a man-hour for that program can be determined. Using only "that year" dollars, with no discount for inflation, the price we pay for a man-hour of shuttle crew time is $38,000. The price paid for an hour of Skylab crew time was $170,000 and the price for an hour of Apollo crew time was $169,000. Gemini was not quite as costly but still more so than the shuttle — an hour of Gemini crew time cost $66,000. An hour of Mercury crew time was over half-a-million dollars.



Delivered-to-orbit price per pound in $ millions

All dollar figures use "that year" dollars. Redstone program cost is computed in 1962 dollars, Shuttle in 1990 dollars. All computed costs use the total program cost (research, development and for the period of operational use, operations costs).

But one could argue that productivity and advantage require the system also put some level of poundage into space — in orbit or on its way to a planetary encounter. This, too, can be measured and gauged against other systems. The poundage must first be defined, and in the case of the Saturn family of launchers, included both the Apollo command and service modules and the Skylab workstation. In the case of the shuttle system, the payload includes what is inside the orbiter bay but also includes the orbiter itself since it is not only reusable but while on orbit serves as a temporary space station. The Saturn family sent 1,801,469 pounds of material into space. The shuttle system has sent 7,237,039 pounds of material into orbit and brought a great deal of that back as well. Again, using total program cost figures, this equates to a per pound cost of between $8 million and $27 million for the Saturn (depending on whether you want to count Skylab separately) and $4.9 million per pound for the shuttle. The Titan cost $13.4 million per pound; the Atlas cost $10.1 million a pound and the Redstone cost $19.8 million a pound.

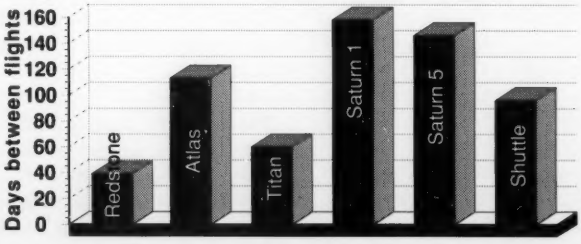
One of the most cited programs in terms of its beneficial effects on human activity, self-awareness, and planetary husbandry has been the Skylab orbital workstation. Part of the advantage of Skylab rested with its repeating orbital track and the synoptic view of the Earth it gave both astronauts and ground-based observers. The year-long triple Skylab missions accumulated 73 million orbital miles. The 36 shuttle missions have built upon that tradition. Indeed many of the shuttle's Earth-observation capabilities and advantages were first learned during Skylab. But the shuttle has gone on and in the decade since it first flew has put another 88 million orbital miles under our collective Earth-watch belt.

The Apollo program cost over $20 billion dollars and had an effective work life — not development life — of 4 years. Essentially, Apollo was the development of docking, rendezvous, lunar navigation and landing techniques. The development of the Apollo command and service modules, the Lunar Excursion Module, and the Saturn V launcher were all essential to carry out the goals of the program.

What is sometimes forgotten in comparisons between the shuttle system and its precursors is that the shuttle is not just a launch system. It is a complete Earth orbital system which happens to be reusable. The development of the shuttle orbiter incorporates everything which has been learned in U.S. space flight experience. An entire Naval fleet has been freed from duty by the evolution from passive to active landing as we went from "splashdown" to "touchdown."

The shuttle is not the end of the development line for U.S. man-rated spaceship and launcher systems. But no one should underestimate just how evolutionary it really is. It is demonstrably more efficient than previous vehicles and launch systems and it has imbued a whole new generation of Americans with spaceflight experience which will bear on the continued evolution of our spacefaring capabilities. ■

Flight rate for man-rated launch vehicles

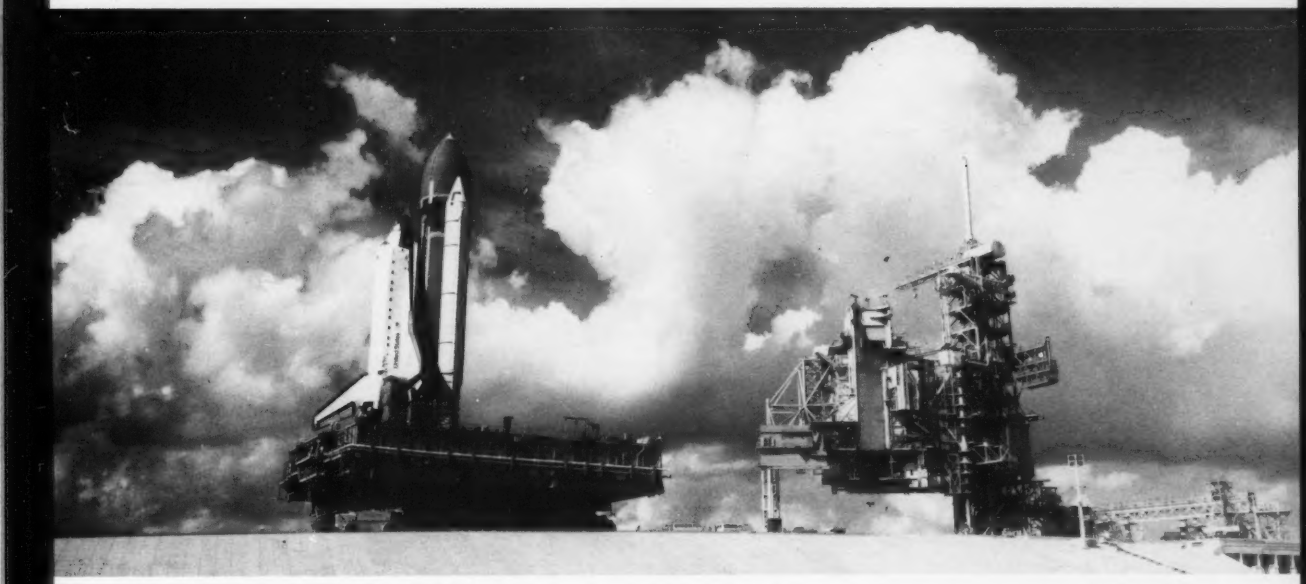


No one knows the Space Shuttle as well as the pilot who flies it

Flying the Space Shuttle: A Pilot's Log

By Dan Brandenstein, Chief of the Astronaut Office and James Hartsfield, JSC

It is the dawn of another long, hot Florida summer day at the Kennedy Space Center. For a place filled with high-tech, heavy industry, the site is eerily quiet, minus even a tick from the digital clock, counting seconds in quartz-timed, 20th-century silence.



In contrast to the flat swamp, in contrast to the gulls that circle as the sun boils from the Atlantic, the space shuttle is graceless, ungainly and out of its element.

One can see it from all angles. From one view, it is a machine, polished, processed and ready. In fact, it is a composite of hundreds of noisy small and large machines and turbines, metals, bolts and seals and washers and plumbing.

From another side, it is the fruit of a thousand careers, jutting in white, black and orange from a concrete pad. In the carbon-carbon tip of the nose are the best and most innovative years of far more than a hundred lives; in the curve of the wings are more years and more lives spent calculating, drawing, designing, testing, and designing again.

To another set of eyes, it is a shell, a lifeguard that will protect its inhabitants from the hostilities it must face to spend just a few days as a world unto itself and return home. The machines, materials and careers that compose the spacecraft are a barrier between the constant, often torturous change it will face outside and the safe haven it must maintain within.

But for all these angles the world can see, only one person at a time can see this machine truly do its job. The left-hand seat is a single seat, and only an individual can know how it flies, or what it looks like, or what it feels like and sounds like and is like.

He is at the controls and in command, and by the time he takes his seat, he is engrossed in the complexity of the machine and the task it will perform. Dan Brandenstein, chief of the Astronaut Office, has taken that seat for two flights, and ridden next to it once. Along with the burden of responsibility a commander carries on board, he carries another when he returns: to describe his journey to the thousands that made it happen. And all they can do is ask.

"When you've had the opportunity to work with the shuttle and fly it, you get a real appreciation for the total team," Brandenstein says. "You really see how broad a scope of folks are involved in it and just how complex it is. And then you see it operate

as well as it does.

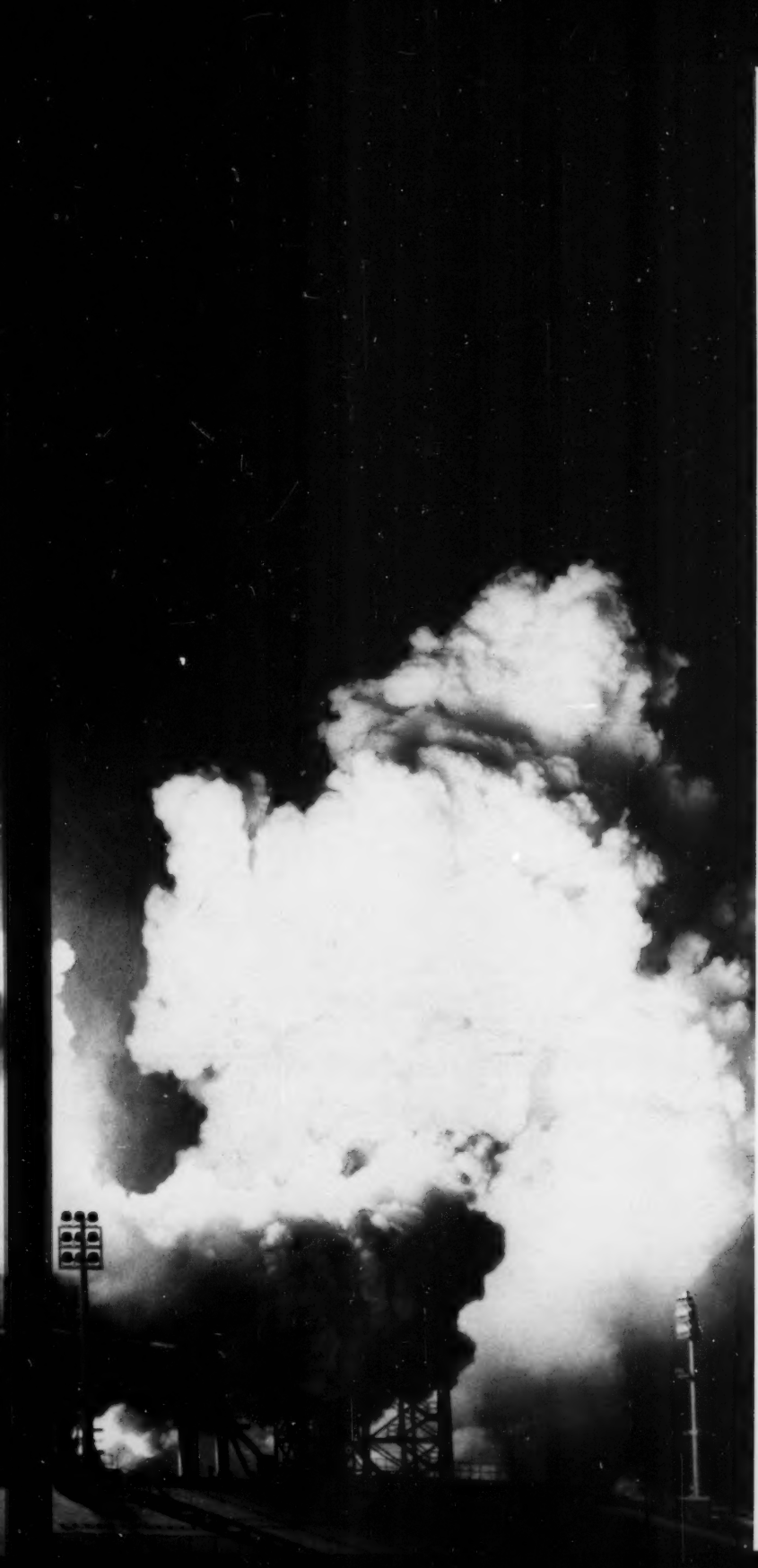
"I really don't think people understand the versatility of the shuttle. I don't think they understand what it can do and really how complicated it is. As a crew member, as a commander, you become more familiar with it. With each flight, you become more familiar with it. But it's just that the more and the better you know it, the more you understand just how elaborate it really is."

When the silent clock strikes zero, more than 250 NASA television and film cameras are trained on the shuttle. Commercial television cameras line platforms three miles away, and the scenes on which they focus are transmitted to every major American network. Still cameras are planted remotely in the swamps around the launch pad; even more cameras click in a press grandstand. And no one counts those that line the roads for 10 and 20 miles around.

At ignition, the solid rockets go from zero to 44 million horsepower in a split second. The main engines produce a power equal to that generated by 23 Hoover Dams.

But all the eyes that study it as a spectacle, both electronic and human, can't see it from the perspective of that single, front left seat.

"If you aren't keyed up, when the boosters light, you ought to get keyed up then. For a certain amount of time, from liftoff through the roll program, you feel you don't have much control to fall back on. The roll program would be a very difficult maneuver to fly manually. Beyond that, we practice flying ascents manually in the simulator, and I feel very confident that if you had to, you could fly it. But the roll program is a very coordinated maneuver. In the simulator, you can fly it, but you can't fly it very well and you can't always fly it.



"You know, I've flown three times on the shuttle, but I've probably looked out the window for only two or three glances on ascent. You are really focused on making sure the vehicle is operating properly. You're cycling through the various displays and you're monitoring trajectory very closely to be sure it's doing what it's supposed to be doing. In that dynamic a region, if it starts to do something wrong, you can't be hesitant. You know what the limits are and when you are going to have to take over manually if something happens."

Eighty NASA cameras still focus on the shuttle at 150,000 feet, two minutes and 10 seconds after launch, when the solid rockets burn out. From the ground, they appear to fall away like arrows at the height of their flight, with a slow grace that camouflages the explosive charges that push them away. The spacecraft is moving more than four times the speed of sound.

"When the solids go, you feel a dip. It feels like you're falling for just a second. It doesn't really do anything like that, but it feels that way. After SRB sep is past, it gets so smooth. I always refer to it like a sewing machine. It just kind of purrs.

"My first glance out the windows on a flight was right after the roll program. You look out then to check for debris going by the windows. The sky was still blue. The second glance after that, there was a little bit of blue, but the sky was mostly black."

For six and a half minutes after the solids have expired, the main engines continue to burn, pulling fuel from the external tank at a rate that would drain an average swimming pool in less than nine seconds. To those watching, it is simply streaking toward space, continually climbing, constantly accelerating and slowly disappear-

ing. But to those flying, it is passing through boundary after boundary, climbing a set of safety-net stairs to orbit.

"You are always busy monitoring systems. You give the middeck folks a slight play-by-play of what's happening now, what's about to happen, to keep them informed. Your concentration on trying to keep track of options does decrease some, though it is more like it shifts. When you pass the negative return call, you don't have to worry about a return-to-launch-site abort. That's one less thing you have to worry about, so you kind of flush that. But you still have a variety of abort boundaries to go through.

"Then, when you get the press-to-main engine cutoff (MECO) call, well, your transatlantic aborts are gone, so you kind of relax on that. But you still have more things ahead.

When the main engines cut off, the shuttle is about 70 miles high and traveling around 17,400 miles per hour. But the sensations in the front left seat say it may as well be sitting still. "The acceleration that pushed you in the seat is gone, and you're just floating."

Going into orbit is a ballet of energy. The 44 million horsepower per second put out by the solid rockets are still within the shuttle. The 23 Hoover Dams per second of the main engines have been imparted to the spacecraft. All that remains to put the shuttle in orbit now is a slight boost, an adjustment, a baby step in comparison to a sprinted marathon, without which the spacecraft would descend as quickly as it rose. The orbital maneuvering system engines are a fine-tuning mechanism, easing the shuttle into a free-fall around Earth, too fast to come down, too slow to go higher, with a gentle push rarely longer than a couple of minutes.

"Relative to the sensations of ascent, the OMS burn is not much. But it is very noticeable. Once you've been in zero-g for a while, any burn is very noticeable. You're more sensitive. The burn is a bit of a jolt when it starts, and it's just a smooth, gentle acceleration after that. You don't really see yourself get any higher. It is so gradual; you do a burn on one side of the Earth and you don't really see that you're any higher until you're half an orbit away.

"You don't relax afterward, because then you're into post-insertion. You're configuring for on-orbit operations. You're opening the payload bay doors, you're stowing the seats and getting out of your suits. You're adjusting all the systems for orbit. It's a very busy time and it normally sets the tone for the mission. You want to get through that and stay ahead of the timeline, because as soon as post-insertion is done, then you start getting into the meat of the mission. You don't want to get behind or get caught short.

"It isn't really until the pre-sleep period on the first day when you can really kind of relax and say, 'We're all caught up; We got today done.' Then you can spend more time looking out the window, and you can eat a slow meal. In fact, for lunch on the first day, we usually just carry a bag of sandwiches we can eat on the run." Brandenstein's first flight, STS-8, launched at night. The shuttle reached orbit in darkness, and created its own new day within a few minutes.

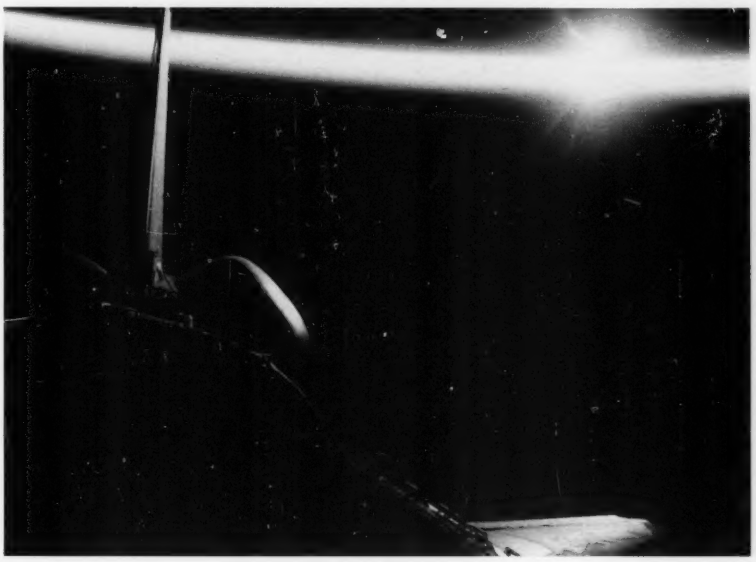
"We launched at night, we crossed the Atlantic at night, and, just as we got to Africa, we saw the first sunrise. Of all three flights, seeing that first sunrise is something that's most memorable to this day. In your training, you get briefed on what things are going to be like: 'ascent is going to be like this.' But no one ever said how phenomenal those sunrises were. And it was so gorgeous, it just took my mind away.

"Sunsets and sunrises happen very fast. At sunrise, you see a sliver of sky turn blue, and then you get this tremendous spectra of color all

along the horizon. The colors are just so vivid and so bright that it is really amazing.

"Through your training, you develop this teamwork. Mission Control is there and is another part of the team. You're part of the team. You don't ever feel alone. I have never felt anything like that on orbit. But you don't feel like they're right next door to you, or like they are always looking over your shoulder, either.

"You have to have what we sometimes refer to in the flying business as 'situational awareness.' You have to know what's going on all around you. You have to have a big picture of all the systems on board. But, then again, by the time we fly, we've been trained by so many experts that we also have a very intimate knowledge of each particular system.



"You have to be able to look at the shuttle in both ways: an objective view of the whole and a narrow, very focused view of a small part. You move back and forth as the situation dictates. When things are going normally, you see the whole. And when you're working a specific problem, you home in on the thing at hand. Once you resolve it, you step back to the whole picture. Still, in general, you'll never know everything.

"I sleep on the flight deck. If something happens during the night, you're right there ready to respond. I sleep in the seat so the rest of the crew can sleep downstairs. If there is an alarm, the controls are right there. You can get to it quickly and not disturb the whole crew, especially if it's something that's not very significant.

"I sleep well on orbit, but I don't think I sleep as soundly as I do back home. I believe it's mainly because I don't want to get too sound asleep just in case there is an alarm or something.

"Day-to-day, when you are doing experiments, eating dinner, or doing housekeeping chores, you let the caution and warning system do its job. You don't monitor things very much. But when you have a spare moment, you go and cycle through the displays."

Flight in orbit is not flight, although it is called that for lack of a better word. Movements of the shuttle in space are adjustments made to a perpetually falling object through the use of 38 primary jets, six small jets or the two large OMS engines. The wings are simply waiting. Due to the unnatural feel of orbital mechanics, flight is now a precise calculation of cause and effect more than it is a human feel for what will occur and why. The idea of any movement at all is relative to where you are looking.

"You don't have a sensation of speed such as driving fast down the road, because poles aren't whizzing past you, you aren't hearing the rumble of wheels on the ground. It's not even like flying an airplane at low altitude, where you see the terrain zipping past, you feel the turbulence and you hear the wind noise. You're in a silent environment other than the cockpit noise, and the only sensation you have is when you look out the windows and see the ground tracking below you. But to see continents come and go, to take on the order of 10 minutes to cross the United States, it's obvious you're really humming. But it's a different sensation of speed. You don't have the acceleration. It's just zero gravity, floating at almost 18,000 miles an hour.

"The reaction control system feels very tight when you are flying close to another object. You fire the primary jets and the vehicle gets a big thump, shakes and it moves. When you get into very close proximity operations, precision flying of the shuttle is based on two things: first, it has a really well-designed flight control system; second, you train a lot.

"You can control it to within

continued on page 23

A Walk Around the Space Shuttle

The Space Shuttle's superlative design provides capabilities and a flexibility unmatched by any other launch system. Here is what makes it work.

The Shuttle's major components are: the orbiter spacecraft; the three main engines, with a combined thrust of almost 1.2 million pounds; the huge external tank (ET) that feeds the liquid hydrogen fuel and liquid oxygen oxidizer to the three main engines; and the two solid rocket boosters (SRBs), with their combined thrust of some 5.8 million pounds, which provide most of the power for the first two minutes of flight.

The SRBs take the Space Shuttle to an altitude of 28 miles and a speed of 3,094 miles per hour before they separate and fall back into the ocean to be retrieved, refurbished, and prepared for another flight.

After the solid rocket boosters are jettisoned, the orbiter's three main engines, fed by the external tank, continue to provide thrust for another six minutes before they are shut down, at which time the giant tank is jettisoned and falls back to Earth, disintegrating in the atmosphere.

The Space Shuttle Orbiter

The orbiter is both the brains and heart of the Space Transportation System.

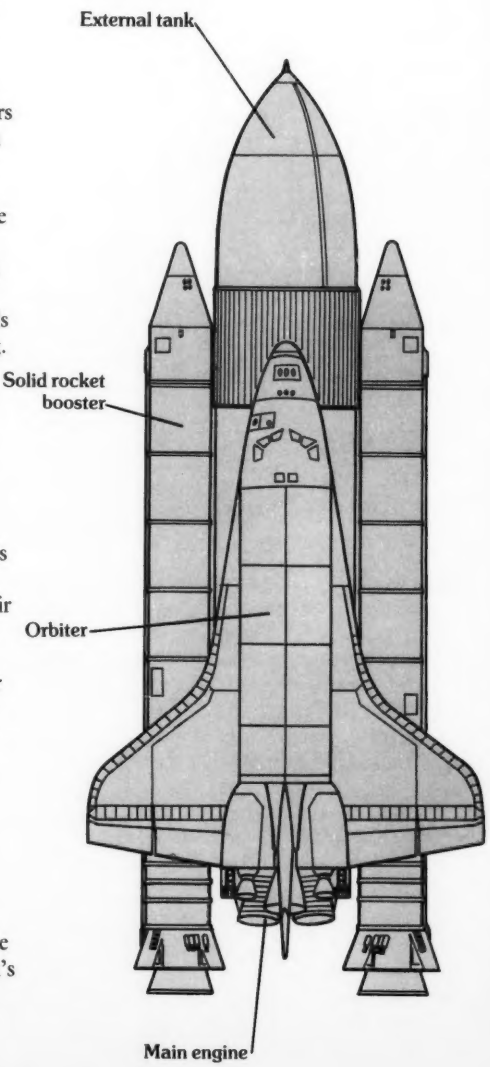
About the same size and weight as a DC-9 aircraft, the orbiter contains the pressurized crew compartment (which can normally carry up to seven crew members), the huge cargo bay, and the three main engines mounted on its aft end.

The thermal tile system which protects the orbiter during its searing reentry through the atmosphere, was a breakthrough technology that proved much more challenging than expected.

There are three levels to the crew cabin. Uppermost is the flight deck where the commander and the pilot control the mission, surrounded by an array of switches and controls. During the launch of a seven-member crew, two other astronauts are positioned on the flight deck behind the commander and pilot. The three other crew members are in launch positions in the mid-deck, which is below the flight deck.

The mid-deck is where the galley, toilet, sleep stations, and storage and experiment lockers are found for the basic needs of weightless, daily living. Also located in the mid-deck are the side hatch for passage to and from the vehicle before and after landing, and the airlock hatch into the cargo bay and space beyond. It is through this hatch and airlock that astronauts go to don their spacesuits and manned maneuvering units (MMUs) and prepare for extravehicular activities (EVAs), more popularly known as "spacewalks." These excursions have produced some of the most important space firsts in the Shuttle program as well as the most spectacular photographic vistas of the space age. Below the mid-deck's floor is a utility area for the air and water tanks and their ducts.

The Space Shuttle's cargo bay is adaptable to hundreds of tasks. Large enough to accommodate a tour bus, (60 x 15 feet) the cargo bay instead carries satellites, spacecraft , and Spacelab scientific laboratories to and from Earth orbit. It is also work station for astronauts to repair satellites, a foundation from which to erect



space structures, and a hold for retrieved satellites to be returned to Earth.

Mounted on the port side of the cargo bay behind the crew quarters is the remote manipulator system (RMS). The RMS is a robot arm and hand with three joints analogous to those of the human shoulder, elbow and wrist. It is operated from the aft station of the orbiter's flight deck. The RMS, some 50 feet long, can move anything from satellites to astronauts to and from the cargo bay or to different points in nearby space.

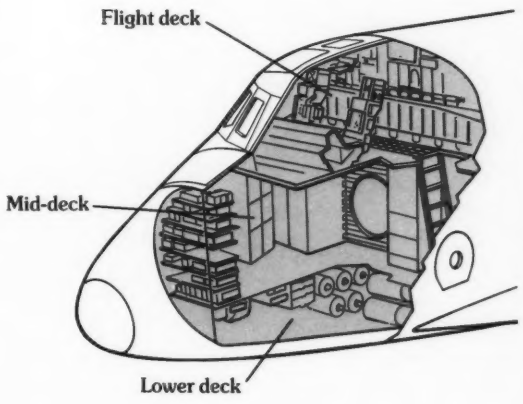
Thermal tile insulation and blankets (also known as the thermal protection system or TPS) cover the underbelly, bottom of the wings, and other heat-bearing surfaces of the orbiter and protects it during its fiery reentry into the Earth's atmosphere.

Designed to be used for 100 missions before replacement is necessary, the Shuttle's 24,000 individual tiles are made primarily of pure-sand silicate fibers, mixed with a ceramic binder. Incredibly lightweight, about the density of balsa wood, they dissipate the heat so quickly that a white-hot tile with a temperature of 2,300 degrees Fahrenheit can be taken from an oven and held in bare hands without injury.

The Main Engines and Orbital Propulsion Systems

The three main engines are clustered at the aft end of the orbiter and have combined thrust of almost 1.2 million pounds at sea level. They are high performance, liquid propellant rocket engines whose thrust can be varied over a range of 65 to 109 percent of their rated power level. They are the world's first reusable rocket engines, designed to operate for 55 flights, and are 14 feet long and eight feet in diameter at the nozzle exit.

Two orbital maneuvering system (OMS) engines, mounted on either side of the upper aft fuselage, provide thrust for major orbital changes. For more exacting motions in orbit, forty-four small rocket engines, clustered on the Shuttle's nose and on either side of the tail, are used. Together they are known as the reaction control system and are used to aid in retrievng, launching, and repairing satellites in orbit.



The External Tank

The giant cylinder, higher than a 15-story building, with a length of 154 feet and as wide as a silo with a diameter of 27.5 feet , is the largest single piece of the Space Shuttle. During launch the external tank also acts as a backbone for the orbiter and solid rocket boosters to which it is attached.

In separate pressurized tank sections inside, the external tank holds the liquid hydrogen fuel and liquid oxygen oxidizer for the Shuttle's three main engines. During launch the external tank feeds the fuel under pressure through 17-inch ducts which branch off into smaller lines that feed directly into the main engines. Some 64,000 gallons of fuel are consumed by the main engines each minute.

Machined from aluminum alloys, the Space Shuttle's external tank is the only part of the launch vehicle that currently is not reused. After its 526,000 gallons of propellants are consumed during the first eight and one-half minutes of flight, it is jettisoned from the orbiter and breaks up in the upper atmosphere, its pieces falling into remote ocean waters.

The Solid Rocket Boosters

The Space Shuttle's two solid-rocket boosters, the first designed for refurbishment and reuse, are also the largest solids ever built and the first to be flown on a manned spacecraft. Together they provide the majority of the thrust for the first two minutes of flight—some 5.8 million pounds.

The solid propellant mix is composed of 16 percent aluminum powder (fuel) and almost 70 percent ammonium perchlorate (oxidizer), with the remainder made up of a binder, a curing agent, and a small amount of catalyst. A small rocket motor in each booster ignites the propellant at launch. During flight, the solid booster nozzles swivel up to a six degrees, redirecting the thrust and steering the Space Shuttle toward orbit. ■

A User's Eye-View of the Space Shuttle

University of Alabama's Charles Bugg talks about the Shuttle from an experimenter's point-of-view

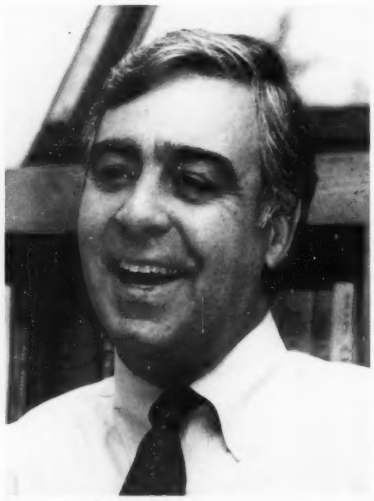
Recently, NASA Activities' Sonja Alexander talked to Dr. Charles E. Bugg of the University of Alabama's Center for Macromolecular Crystallography concerning the shuttle borne Protein Crystal Growth Experiments. Bugg heads an effort to understand protein crystal growth in microgravity conditions.

In March, 1989, the Space Shuttle Discovery lofted into orbit the Protein Crystal Growth Experiment, part of a long-term series of experiments in microgravity protein crystal growth using the Space Shuttle. The overall objective? To develop forefront techniques for using microgravity to produce high-quality crystals of biological materials for structural and pharmaceutical development research investigations.

Crystals resulting from these experiments are examined by X-ray diffraction techniques, which reveal the overall architecture of the biological molecules, if the crystals are of sufficient quality. The resulting structural information can be used to design highly specific pharmaceutical agents for intervening in a variety of different diseases.

NASA Activities: **What unique capabilities enable the experiments to be successful?**

Dr. Bugg: The unique capability is a carefully controlled microgravity environment. Microgravity offers two primary advantages: First, sedimentation processes are eliminated in the absence of gravity. On earth, when crystals grow from solution, they normally sink to the bottom of the container. This sedimentation causes the crystals to grow in a non-uniform environment, resulting in deformed crystals. In the absence of gravity, crystals grow suspended in the solution, bathed on all sides uniformly by the growth medium. Thus, the crystals can grow uniformly in microgravity. Secondly, in the absence of gravity, density-driven convective flow is essentially eliminated. Convective flow results any time a crystal grows from a solution on earth. Convective flow can interfere with controlled uniform growth of protein crystals.



Dr. Charles E. Bugg

NASA Activities: **What is the necessity of the crew to the experiments?**

Dr. Bugg: These experiments have been designed to be performed in the mid-deck of the space shuttle. This permits experiments to be performed by members of the crew, and the equipment has been designed to take advantage of crew operations. By using crew members, automation requirements have been minimized. This increases reliability, and permits experiments to be performed where the outcome is somewhat uncertain. Trained crew members can respond to unexpected experimental events, which adds new dimensions to the possibilities of doing forefront research on the space shuttle. We routinely use crew members to activate and deactivate the experiments, to photograph interesting features that result in the crystal growth solutions, and to note any unusual events that occur during the experiments.

NASA Activities: **How do we handle the data to maintain accuracy?**

Dr. Bugg: There are a number of uncertainties involved in any space experiment. There are a number of other activities occurring on the shuttle, which can interfere with the performance of ideal experiments in protein crystal growth, so control of accuracy in experimental procedures is not always completely ideal. The availability of crew members permits us to note and respond to any unusual occurrences that are unexpected. One way that we try to control accuracy is by performing repetitive experiments, both on an individual shuttle flight and on successive flights. Each protein examined on STS-29 was included in several different experiments on that flight. In addition, most of these protein crystal growth experiments either have been done on earlier flights or will be repeated on later flights.

We try to obtain detailed photographic records and continuous recording of key parameters, such as temperature, in order to document the experimental results in orbit. The samples are returned immediately to Birmingham for complete laboratory analysis within several hours of the time that the space shuttle lands, and these detailed analyses allow us to analyze the accuracy of the data.

NASA Activities: **What is the quality of data and experimental results due to use the shuttle?**

Dr. Bugg: The main advantage of the shuttle is that it provides a microgravity environment for performing protein crystal growth experiments. There are some significant advantages of the shuttle, relative to other options for accessing space. The shuttle permits us to load our sensitive biological materials immediately prior to launch, and to retrieve these materials from the mid-deck immediately after the shuttle returns to earth. The shuttle has a mild re-entry, with low g-levels, which permits us to return crystals to earth without significant physical damage. The shuttle provides crew members who are able to perform complex experiments.

The main disadvantage of the shuttle is that is in orbit for only short periods of time, which limits the number of proteins that can be examined. Another disadvantage of the shuttle is that disturbance due to crew activities, such as exercise regimens, can interfere with certain types of crystal growth experiments.

Overall, the experimental results to date indicate that the space shuttle can be used in certain cases to produce protein crystals that are significantly better than the best crystals of these same proteins produced on Earth. These higher quality crystals permit unique biomedical and pharmaceutical development projects to proceed.

NASA Activities: **What are the future plans for Shuttle in your research?**

Dr. Bugg: We are scheduled to fly on a number of shuttle flight missions over the next six years. These flights will permit development of new approaches for protein crystals growth in space, and the development of new hardware for optimizing the effects of microgravity on protein crystals growth processes. We now have 60 Co-Investigators from academic, government and industrial laboratories working with us on this project. These various Co-Investigators are studying a wide range of different proteins and different crystallization problems that are likely to benefit from microgravity research in this area. Future plans include the development of equipment and techniques that permit dynamic control of protein crystal growth processes in microgravity.

Overall, the experimental results to date indicate that the Space Shuttle can be used in certain cases to produce protein crystals that are significantly better than the the best of these same proteins produced on Earth.

NASA Activities: **What are the medical advantages of the research?**

Dr. Bugg: Structural biology is of major basic interest in all fields of medical research. Crystallography is the only technique for determining the arrangement of atoms in the three-dimensional structures of proteins and other large biological molecules. The structural information gained by studying crystals of biological materials permits investigators to understand how various important molecules function in biological systems, and how these functions can be modified in order to solve different specific medical problems.

From the applied standpoint, the information gained by protein crystallography is extremely useful in designing new pharmaceutical for treating a wide range of human diseases. Experiments to be included in future shuttle flights are directed at proteins and other biological molecules that are of key importance in developing pharmaceutical for use in cancer, AIDS, arthritis, diabetes, influenza, cardiovascular diseases, emphysema, and in a variety of other illnesses.

The overriding limiting step in applications of protein crystallography is protein crystal growth. It is not possible to pursue these structural studies, or to use the structural information for designing new pharmaceuticals, unless highly-ordered crystals of the materials can be obtained. Crystallizing most of these biological macromolecules is extremely difficult on earth. Results to date indicate that microgravity can be used effectively to greatly enhance the quality of biological crystals, and it is expected that the future space experiments will further enhance the potential of microgravity protein crystal growth. ■

Musings of an Unabashed Shuttle Apologist

By Brian Welch, JSC

Expectations seemed to crumble as the dog days of summer, 1990, brought a plethora of technical problems to the space agency.

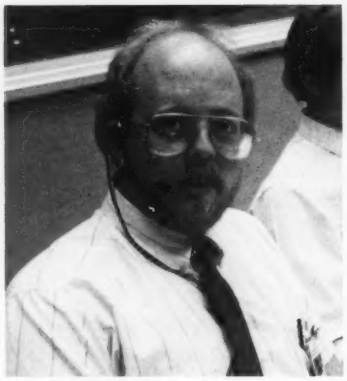
In early August, TIME Magazine's assessment was that "with the shuttle grounded, the Hubble troubled and its future role in jeopardy, NASA is an agency lost in space."

By summer's end, after an agonizing series of repairs and leak checks with Columbia and highly publicized processing mishaps with Atlantis and Discovery, Americans could be forgiven for thinking that the whole damn fleet was just barely hanging together with chewing gum and bailing wire.

In a letter to the Houston Post, under the subhead "Shuttle shame," a concerned citizen demanded to know, "What kind of turkeys have we got working on that space shuttle?"

A few weeks later, after sending Ulysses on its way to study the Sun, Discovery returned to Earth, landing at Edwards Air Force Base Oct. 10 and bringing to a close what was uniformly thought to be a flawless mission. Had anyone bothered to report the number of anomalies tracked during STS-41, the concerned Houstonian might have gotten an answer to his question.

When Discovery came to rest Oct. 10, it had completed its eleventh orbital flight and had logged more than 23 million miles on the airframe. By comparison, Apollo 11's Command and Service Module, a one-of-a-kind vehicle built for a single unique event—traveled less than 1 million miles and, post flight, had 11 anomalies written up by the mission analysis



Brian Welch

team. The Lunar Module on Apollo 11 had fourteen anomalies, and three problems were noted with the government furnished equipment for the mission.

Discovery, on the other hand, having flown in her time more than halfway the distance to Mars, had exactly five anomalies, none terribly significant, and one of those was simply an image burn-in due to overexposure of one of the payload bay cameras!

The significance of these numbers was not widely noted.

* * *

Americans have never been particularly adept at taking the long view of things, especially when it comes to savoring the nation's accomplishments in air and space, but if nothing else we are at least consistent. Even in the beginning of the age of flight, our criticism of the unknown could be scathing.

As the year 1903 drew to a close, for example, things were not going especially well for Dr. Samuel Pierpont Langley, secretary of the Smithsonian Institution, who was trying to make his Aerodrome fly.

Twice in 1903, Langley tried to get the Aerodrome aloft by catapulting it from the top of a squat wooden houseboat in the middle of the Potomac River. The Aerodrome simply would not fly, and this fact was not lost on the many reporters who watched it happen.

Langley was characterized as a doddering old fool by the press ("pilloried," is how one historian described it), and his research was depicted as a misbegotten waste of the $50,000 with which the War Department had seen fit to entrust him. Langley, it is said, never quite recovered from the drubbing he took in the newspapers.

Farther south along the Eastern Seaboard, Wilbur and Orville Wright were busy with their own experiments. Nine days after the Aerodrome went nose first into the Potomac, the winds were brisk over Kill Devil Hill along the North Carolina seashore and the Wright Flyer made four short hops into the sky. A small crowd, including several reporters, had gathered to see what these Ohio boys were up to. Somebody even took a picture.

A telegram was received in Dayton, Ohio, and read:

SUCCESS
FOUR FLIGHTS THURSDAY MORNING
ALL AGAINST TWENTY-ONE MILE WIND
STARTED FROM LEVEL WITH ENGINE POWER ALONE
AVERAGE SPEED THROUGH AIR THIRTY-ONE MILES
LONGEST 59 SECONDS
INFORM PRESS
HOME CHRISTMAS

ORVILLE

In 1903, America was far from the global media village it is today and only three newspapers carried accounts of the flights on Kill Devil Hill. For five years, the significance of the flights was either misunder-

stood or ignored altogether by the press and the public.

If you are looking for a connection—other than the purely technological—between the Wright Flyer of December 1903 and the space shuttle Discovery of October 1990, this may be it.

* * *

More than three quarters of a century after Dr. Langley and the Wright Brothers, America has managed to develop a machine which can rocket to space, ply that silent sea with remarkable precision, and then return to the surface of the planet in winged flight. If one accepts the notion that ill-informed criticism is a common thread in the history of American flight, and is thus willing to judge the shuttle as a technical achievement alone—quite apart from its enormous political baggage—then what does that tell us about these orbiters we've been tinkering with for the last 20 years? Was it worth it? What did we come up with, and where, then, does the Shuttle stand in the vast pantheon of flying vehicles?

Well, for starters, the American space shuttle stands completely unmatched, technically, by anything with or without wings on or off the planet. The shuttle, as a for true and for real first-generation going-to-space-and-back vehicle, stands astride the aerospace world of late 20th century Earth like a colossus. There simply is nothing like it anywhere, and no other nation on Earth could bring to bear the excellence in so many disciplines necessary to think of it, build it and fly it. And not just once, but almost 40 times.

Perhaps the best place to begin in understanding the shuttle's place in history is to go back to the heady days of the program following the first flight in April 1981, exactly 20 years after Yuri Gagarin rode a tiny capsule into orbit.

For Tom Wolfe, writing in National Geographic a few months after Columbia's maiden voyage, there was a sense of historic closure in the flight of a winged spaceplane. "To me there was a touch of Rip Van Winkle about it all," Wolfe wrote. "After 54 hours in earth orbit an airplane—not a capsule or a command module, but an airplane, a ship with wings—descends above the high desert of California. It glides toward a landing at Edwards Air Force Base. As in the old days, the mirages of Rogers Dry Lake envelop it like a hallucination."

The flight, Wolfe said, resumed "a story that was broken off a quarter of a century ago. It returns the American space program to where it started..." He was among the first to point out that the Columbia is a direct descendant not of the Apollo or the Gemini or the Mercury, but of the X-15 and the X-1, both of which were designed by the wizards of the NACA.

By the dawn of the space age, the old hands at Edwards had already made a habit of exceeding the speed of sound twice over and were about to go off and fly the X-15. Just about the only thing holding them back from going full bore, hellbent-for-leather straight into low Earth orbit and back, as envisioned by the designers of the X-20, the Dyna-Soar, was the heat of reentry and some of the finer points of flight control.

But there was also the question of funding. When the challenge of Apollo was first proposed by President Kennedy in May 1961, the total U.S. experience in space flight was Al Shepard's 15-minute suborbital hop. No matter. Ballistic flight, with capsules lofted off-planet by large rockets, was clearly the way to go and held out the best prospect of getting the most payload into space and on its way to the Moon in the least time.

For the people who had grown up testing airplanes for the NACA, this was a new and complicated business. Dr. Christopher C. Kraft Jr., former director of JSC, noted in a 1988 speech that the demands of the new science of space flight were "anything but routine."

"The effects of the space environment on man and machines, particularly that of zero gravity," Kraft said, "created a whole new set of design requirements foreign to the world of flight.

But as the age of air gave way to the age of space, the engineers whose careers straddled both epoches were flush with excitement at the new lessons they now had to learn. By 1962, Project Mercury was coming to a close, but three other spacecraft were being readied in the wings—the Gemini capsule, the Apollo Command and Service Module and the Lunar Module—and the young agency was hard at work on three space flight programs simultaneously.

In that process, the U.S. built very expensive vehicles and used them only once. It was, Wolfe wrote, "like buying a new Buick Electra 225 every time you drove over to the Seven-Eleven." All of that changed once the goal of landing on the Moon had been satisfied. That is when, as Wolfe wrote, "NASA returned to the task of developing a rational and affordable system for flight in earth orbit. Which is to say, the X-20 project, reborn as the space shuttle."

With the temporary diversion of JFK's lunar mission now out of the way, it was time to continue with the natural evolution of American spaceflight. It was to be, as former NASA Administrator Thomas O. Paine has observed, "an unprecedented vehicle."

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BIOGRAPHY

(Biography is written by members of the NASA History Division)

Maxime Faget and The Space Shuttle

By Sarah Turner, Hq

Maxime Faget, internationally known as the chief designer of the Mercury spacecraft, has played a major role in developing the basic ideas and design of every manned spacecraft the United States has ever flown, including the Space Shuttle.

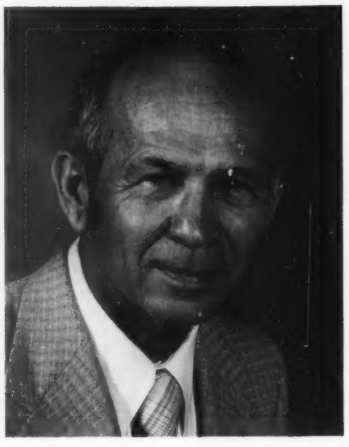
After Navy submarine service during World War II, in 1946 he joined the staff of the National Advisory Committee for Aeronautics (NACA) Langley Aeronautical Laboratory. Faget developed a method of measuring engine inlet performance, designed a record breaking ramjet test flight vehicle, and developed a ramjet burner and fuel control system. His concepts for the Scout four-stage booster, the Little Joe booster, a wingless hypersonic glider, a four-engine supersonic bomber, as well as the preliminary design of the X-15 rocket plane, followed.

In the late 50s, as NACA turned toward the study of manned spaceflight, Faget presented a paper showing that a simple ballistic-shaped spacecraft could reenter the atmosphere without experiencing high temperatures that would be dangerous to man.

In addition, the paper argued that the spacecraft could be brought back from orbit by using small retro rockets and that attitude control could be maintained by using arrays of rocket thrusters. The paper also described the use of parachutes for the final descent.

In October 1958, as NACA became NASA, Max Faget was assigned to the Space Task Group (STG), which was established for one purpose only — to place a man in earth orbit and return him safely to Earth. Called Project Mercury, it relied heavily on Faget's concepts and ideas.

Plans were made during the design phase of project Mercury for follow-on projects. Faget centered his studies around two primary objectives — longer duration space flight and the rendezvous of spacecraft. Both objectives, however, required major upgrading of the spacecraft and its propulsion system and the results eventually led to the two-man Gemini vehicle.



Maxime Faget

During this same period plans were made for the Apollo Program. Faget was directly involved in the design and development of the spacecraft and onboard systems. He acted as both the Manager of Engineering and Development, as well as the technical expert for systems integration.

By 1968 Faget's interest in manned spacecraft was taking a new turn. He reflected, "exploration was coming to an end ... reusability was the thing to me. I knew we had to get to that to cut down on cost. I could see what space could be used for, not a complete understanding, but I could see a lot of benefits." That vision was to be the Space shuttle.

In May 1969, at JSC Center Director Robert Gilruth's direction, Faget Presented a concept of a piloted, vertically launched, two stage, fully reusable, horizontal landing vehicle—a "DC-3 Space Shuttle". Both the orbiter and booster were aircraft-like vehicles with straight, fixed high aspect ratio wings. Mating of the orbiter and booster was piggyback with the belly of the orbiter attached to the upper forward fuselage of the booster.

Faget was responsible for integrating all the engineering activities throughout the shuttle concept and study phases. Over time the design concept changed. Demands for larger payloads required that the fixed wings be dropped in favor of a delta swept wing configuration. Also gone were the wings on the booster. As the program progressed Faget and his team of engineers assumed the responsibility for the technical requirements and management of all hardware subsystems in the shuttle orbiter.

After the first two successful shuttle flights Faget retired from NASA, however, his interest in developing new concepts of spacecraft did not end. Faget is currently president and chief executive officer of Space Industries, Inc., and has developed and designed the Industrial Space Facility (ISF), a man-tended, automated free-flying laboratory concept.

Clearly, Maxime Faget is still in the forefront of the exploration of space and the reaping of its benefits. ■

***A Pilot's Log*, from page 15**

inches this way or inches that way relative to the task you're trying to accomplish. We did that when we retrieved LDEF, and we did that when we retrieved Spartan on my second flight. The flight control system holds an attitude so well, and it makes flying it so precise, you can make very specific movements.

"It is a tribute to how well designed it is. That's the type of control you have. Still, you can't always get it perfectly stopped relative to another object, so you might just move it so far and let it take a very slow drift."

The only time the shuttle's speed is constant is when it is in orbit. To go from zero to almost 18,000 mph in eight and a half minutes is a feat, but the bigger feat is to go from 18,000 mph to zero and remain intact. The shuttle poses for its return to air and wind and land like the traveler who pulls coat collar tight and puts chin and chest into a bitter winter breeze: It takes a posture of defiance. To designers, crew and flight controllers, it is called a high angle of attack; its nose is angled high, and its most durable portion, the tiles underneath, greet Earth first in a battle between air and speed.

"The deorbit burn feels just like the OMS burn on ascent. But as soon as you're done with it, you pitch around to get the nose forward and up. Then, as you start your fall toward the atmosphere, you do notice that you're coming down. It looks like you are getting closer to the Earth. But you normally go into night very quickly, and then your visual cues are gone.

"Then, in darkness, the first sensation you get is when you are a bit into the atmosphere and the Gs start building up. It still doesn't feel like a descent; it feels like being in an airplane and pulling Gs. It just feels like you're squishing down in the seat. The only real sensation of descent is from watching the altimeter click off.

"From the sensations, without instruments, you wouldn't know the difference between Mach 25 and Mach 1."

The shuttle's entry is automated from the deorbit burn through three gradual, sweeping S-turns, one of which can take half an ocean to complete. The atmosphere is the only brake it has to slow it from Mach 25 to 200 miles an hour. The friction between air and spacecraft produces temperatures of almost 3,000 degrees Fahrenheit. To release the energy it received at launch, it creates as much of a spectacle on entry.

"You don't get used to seeing the plasma build up. At about 350,000 feet, you start to see a little pink out of the windows, coming up from the bottom.

"It turns into kind of a pink glow, and, from that, becomes an orange glow. It then becomes a very deep orange, before it turns practically white — it is so hot. The plasma flow is that dense. In fact, on the corners of the windows, you can see a turbulent flow with swirls in it. It's sort of like rain on the car window, but it isn't drops, it's a flow pattern.

"Then at about 180,000 feet, it goes in reverse: the white gets less dense, then it goes to orange, then pink and then it's gone.

"During this phase, you come into daylight. The Earth is still dark, and the upper part of the sky is still dark, and in those areas you can still see the plasma. But where the sun is rising, you can't see it because of the light background. On both extremes, you have the orange, pinkish plasma. In the middle, you have a blue stripe where the sun is coming up. It only lasts a few seconds.

"You've trained to the point where you know that if you had to take over, you could do it. But you don't even hold your hand on the stick all the time during entry. You are just monitoring systems, cycling through displays on the screens, and checking them against your checklist cards. It's a very close analogy to an airplane on autopilot, though you are monitoring things very closely.

"When you see the sun come back up again, it's obvious that you're much lower than you had been. But even then, when you break out of night, you don't have a sensation of going down. You still feel mostly just a forward velocity."

As the shuttle descends and slows, the jets that have kept it stable are replaced by the rudder and elevons for control. Flight becomes flight again in the traditional sense.

"You can hear the primary jets fire, and you can see them in front. But you don't hear wind noise, and you don't hear much of anything except what is coming through your headset.

"You don't notice the change from the jets to the aero-surfaces; it's very subtle.

"When we go subsonic, at about 60,000 feet or so, we take over manually, flying it around the heading alignment circle all the way to touchdown. That way, when you get to the landing phase, you're in tune with the vehicle. You're aware of its responses.

"The shuttle goes through 'Mach buffeting' as it goes subsonic. It's a shaking kind of like a car going down a gravel road, due to air transitioning from supersonic to subsonic flow over the wings, and it lasts about 10 to 15 seconds.

"It flies very crisply. It is very adaptable. The digital flight control system allows it to respond very much the same with different centers of gravity and different weights.

continued on next page

***Musings*, from page 21**

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Everything that had been learned in the first decade of spaceflight, and in all the years of flight research before that, was folded into the mix. The shuttle was the sublime creation of the world's best and most thoroughly dominating aerospace community at time when that community reached full stride on a global stage.

The Shuttle would weigh almost 70,000 pounds more than the Skylab orbital workshop yet flight controllers would have more than three times as many sensors aboard, and 700 times more insight into its inner workings than they did with the Mercury capsule. Where there were four computers with 50 operational modes on the Apollo CSM, there were five computers with 140 modes on the shuttle. Where Skylab had 30 electrical busses with 540 circuit breakers, the shuttle would have 110 busses with 1,445 circuit breakers.

Where in Gemini we once scared the hell out of ourselves when a stuck-on thruster began spinning the capsule out of control, the Shuttle moves with easy grace through the sea of space, and can maneuver with the precision necessary to become a first rate astronomical platform. By contrast to the early days, when men and machines were whizzing about on unique missions, each seen as individual stepping stones, the shuttle program has demonstrated an empirical truth, and that is that this is an evolving program. It has no end.

While 20 years after Apollo the veterans of that golden time look on their handiwork and can smile the smile of champions, it should be clear that those voyages were close run things.■

Commander & Ed
BY REINERTSON
HOLIDAY TRAFFIC, ED...WE'D BETTER SLOW DOWN & LET THIS JOLLY GENT DEORBIT BEFORE US.
NASA
NICE TOUCH COMMANDER, BUT HE'S ALREADY MADE HIS LIST OF WHO'S NAUGHTY & WHO'S NICE! --SEASON'S GREETINGS, FOLKS!

***A Pilot's Log*, from page 23**

"I've flown 747s and the KC-135, which are big airplanes. In them, you have a certain lag in the responses. But the shuttle flies more like a fighter than a big airplane. You know you are flying a large aircraft, but the controls are positive and crisp.

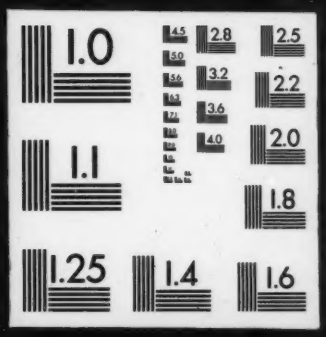
"You don't get much of a sensation of descent until you drop the nose on final. The approach pattern is much different than a fighter, carrier approach or anything else. In the shuttle, you have no power, and most of the time you're constantly decelerating. On the outer glide slope to the runway, maintaining a constant speed of 290 knots, and it's pretty steep. You're kind of hanging in the straps then. You keep your speed constant by opening and closing the speed brake. You feel the speed brake take hold and you feel the drag in general."

On its final approach to the runway, the shuttle descends seven times more steeply than a commercial airliner. It is dropping from the sky 20 times as fast. Less than 2,000 feet above the runway, it pulls up to reduce its angle of descent to just slightly less than that of an airliner. Its final maneuver before touchdown is a slight flare upward of the nose, to slow it even more and allow a gentle easing down of the nose landing gear after the main gear has touched Earth.

"You don't feel the final flare. The only big difference on touchdown is between the lakebed and the concrete runway. Rollout on the runway is much smoother. The lakebed is pretty rough.

"If you bring it to touchdown right, you hardly notice it. It's smoother than a landing in a commercial jet."

"It is being a part of a team that accomplishes a mission that you remember. That's the whole thing. You take it in steps. You're proud of your part in it; your proud of your crew; you're proud of everyone that worked on the flight; and you're proud of the whole team that made the shuttle perform. When you walk away and you're all done, that's what you remember and that's what really makes you feel good."■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